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DDS-3: Enhancing DAT Reliability, Capacity, and Performance

Mid-size businesses and branch offices using departmental servers with storage requirements of 24 GB or less and running Microsoft Windows NT®, Novell NetWare® 3.x or IntranetWare® 4.0 have a growing need for high performance, high capacity, and reliable backup methods. Digital Data Storage-3 (DDS-3) technology, which is the recording format used by Digital Audio Tape (DAT) products, meets this need with three times the capacity and twice the data transfer rate of DDS-2 technology and offers improved automated head cleaning mechanisms that enhance backup reliability. DDS-3 also provides low total cost of ownership for customers, due to low-cost media and backward read/write compatibility with existing DDS-1 and DDS-2 media.

This brief discusses DDS-3 technology and the Compaq 12/24 gigabyte (GB) DAT Drive, which is designed with DDS-3 technology.

Please direct comments regarding this communication to the ECG Technology Communications Group at this Internet address: TechCom@compaq.com

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DDS-3: Enhancing DAT Reliability, Capacity, and Performance
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INTRODUCTION

An efficient, reliable, and cost-effective solution for backup of critical data is a requirement for companies of any size. Compaq bas a strong record of providing industry-standard storage solutions to fit a variety of customer needs. Not everyone requires hundreds of gigabytes of storage or can afford the more expensive backup solutions designed for customers with much heavier backup loads. Increasingly, small and mid-size businesses use departmental servers, such as the Compaq ProLiant 1200, ProLiant 1600, or ProLiant 2500 servers with storage requirements of 24 GB or less. To meet the needs of mid-size businesses, Compaq has an affordable line of DAT drives that use the DDS recording format and provide fast, reliable data storage.

This brief explains DAT and DDS technologies and the performance improvements of DDS-3 over DDS-2. This paper also explains why DDS-3 provides low total cost of ownership. Finally, tbis brief describes the Compaq 12/24 GB DAT Drive with DDS-3 format, including the backup software that it supports.

BACKGROUND INFORMATION

DAT technology was initially developed for consumer audio recording. DDS is a data storage format that was developed from DAT to provide high-density, high-quality, reliable computer data backups. The physical media (drive and tapes) are referred to as DAT, while the recording format is referred to as DDS.

What is DAT?

DAT is a digital recording technology that uses 3.81mm (0.15-inch) wide tape in a *helical scan* read/write recorder. Unlike other tape technologies that only have tape movement, helical scan has both tape and bead movement. With tape and head movement, the tape speed is slower, incurring less tape wear and maintaining better control of the tape as it moves through the tape path. The read and write heads in a drive that uses belical scan are attached to a rotating transport drum, whicb sits at a 6-degree angle to the tape media (Figure 1). Data is recorded in diagonal stripes from bottom to top on the tape, which moves in the same direction as the drum.

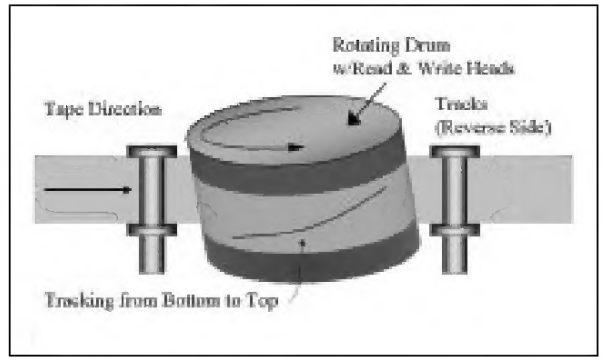

Figure 1: DAT helical scan recording.

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The drum in a DAT drive incorporates two read and two write heads, which are diametrically opposite one another (Figure 2).

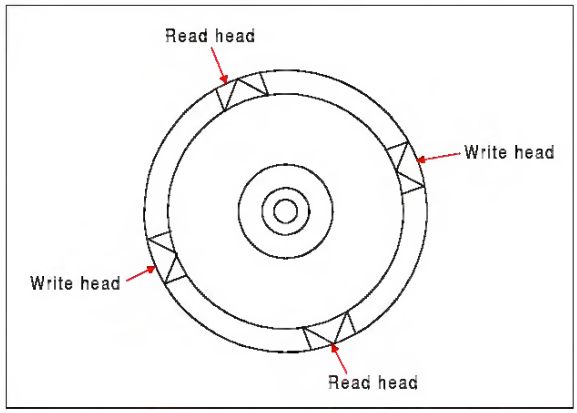

Figure 2: Top view of drum and diametrically opposite read and write heads.

Because the write heads in a DAT drive are set at diametrically opposite angles, they record data on adjacent tracks at angles that vary by +20° and -20° (Figure 3). Recording data in diagonal stripes greatly minimizes magnetic crosstalk. *Magnetic crosstalk* is the interaction between signals from different tracks.

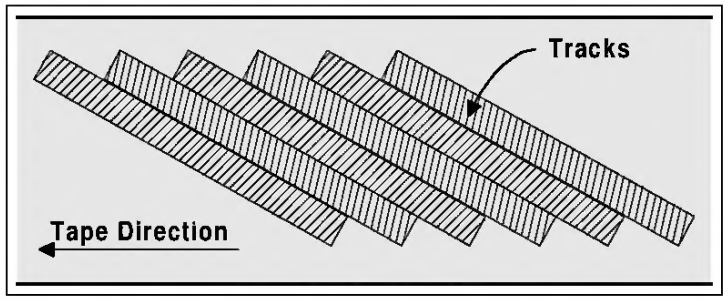

Figure 3: Adjacent tracks are recorded at opposite angles, minimizing magnetic crosstalk.

Compaq DAT Drive Product Line

From the DDS format specification, Compaq developed a series of DAT drives using DDS technology, the first of which was the 2/4 GB DAT Drive (DDS-1), followed by the 4/8 GB DAT Drive (DDS-2). With the advent of DDS-3 technology, Compaq developed the 12/24 GB DAT Drive, which has a capacity of 12 GB native (uncompressed) and 24 GB compressed.

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ADVANTAGES OF DDS-3

In comparison to DDS-2, DDS-3 technology provides significant improvements in capacity, transfer rate, and reliability. When considering all the new features, the drive price, the media price, and the overall reliability, it is easy to see DDS-3 also offers a low total cost of ownership.

Increased Capacity

Although DDS-3 cassettes use almost the same length of tape as existing DDS-2 cassettes, DDS-3 has three times the native capacity (12 GB vs. 4 GB). Factors contributing to this increased capacity include:

- Increased linear bit density
- Increased format efficiency
- Increased use of track space

Increased Linear Bit Density

DDS-3 was originally intended to have a native capacity of 8 GB, twice that of DDS-2. However, the development team discovered that the linear bit density could be increased more than they originally thought. In fact, the density was doubled from 61,000 bits per inch (bpi) to 122,000 bpi. While this doubling of the linear bit density does not result in double the capacity, this increase does significantly impact the capacity of DDS-3.

The capacity of a tape is almost doubled with data compression, depending on the nature of the data heing compressed. Typically, text can be compressed at a 2:1 ratio, while graphic files can be compressed at a 5:1 ratio. However, a file that is already compressed will not compress further during the backup.

Increased Format Efficiency

DDS-3 also has increased format efficiency over DDS-2 due to *Partial Response Maximum Likelihood* (PRML). PRML is a technique used to differentiate a valid signal from random noise. Noise results in data errors. Because DDS-3 has PRML, it incurs fewer data errors due to random noise.

Increased Use of Track Space

In multiple ways, DDS-3 technology increases the amount of track space that can be used to store data. First, DDS-3 uses the *timed tracking* servo format instead of the *embedded servo* format used in DDS-1 and DDS-2.

Servo tracking is a scheme used to regulate positioning and seeking operations in disk and tape drives. This scheme relies on positioning data recorded on the media surface to generate correction signals for the servomechanism. A system with an "embedded" servo, as in the Compaq 2/4 GB DAT and 4/8 GB DAT drives, uses the *automatic track following* (ATF) method to ensure the tape head is in the center of the track being read. There are ATF areas emhedded at the heginning and end of each track; user data is recorded between them. The read and write heads are wider than a single track, so the head reads the ATF areas from the two tracks on either side, as well as that of the track the head intends to read. By comparing the content and strength of the signals from the ATF areas, the servo system adjusts the drum and tape and allows the head to pass directly over the centerline of the track being read (Figure 4). The ATF areas of the track cannot be used to store data.

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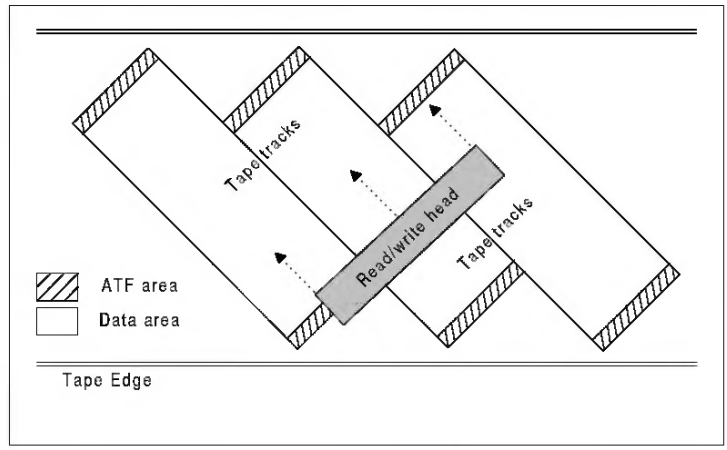

Figure 4: By reading ATF information from tracks immediately left and right of the primary track it is reading, the head centers its position on the track.

The Compaq 12/24 GB DAT Drive does not use embedded servo tracking with ATF. Instead, it uses a *timed tracking* scheme that frees the ATF areas for user data, thus increasing the storage capacity.

Timed tracking is a track-following servo format that provides servo input by measuring the time required for read or write heads to scan from the tape edge to a known reference point on the track. These reference points are equally-spaced "timing marks." By referencing from the edge of the tape, the drive is able to measure the time it takes to reach the timing mark (Figure 5). Any deviation in time indicates a deviation from the track centerline. If the timing is too early, the tape speed increases to center the head on the track; if it is too late, the tape speed decreases. This process increases efficiency and performs head/track alignment more frequently than the embedded servo format. The timed tracking format does not require ATF storage on the track, so more of the track is available for storing user data.

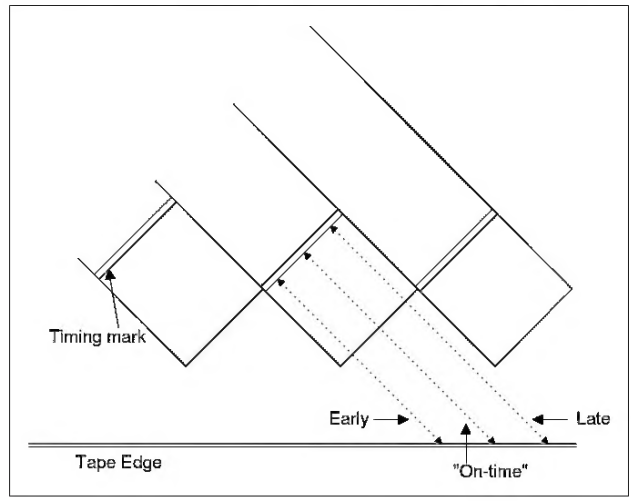

Figure 5: Timed tracking servo.

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Other ways DDS-3 technology increases track space are by compressing sub-code information into less space and by packing user data into fewer, larger blocks, thereby reducing total overhead for data blocks.

As a result of the increased linear bit density, format efficiency, and increased use of track space, DDS-3 has three times the track space that DDS-2 has available for data storage instead of timing, sub-code, Reed-Solomon ECC, and block overhead (Table 1).

Table 1: DDS storage capacity comparison.

DDS Version	Native Capacity (uncompressed)	Compressed Capacity
DDS-1	2 GB	4 GB
DDS-2	4 GB	8 GB
DDS-3	12 GB	24 GB

Faster Transfer Rate

DDS-3 has a maximum native data transfer rate of 1 MB/s (2 MB/s with compression), which is nearly double that of DDS-2. This increase is due in part to the change from embedded servo format to the more efficient timed tracking format. The increase in frequency/bit density also plays a part in the faster transfer rate of DDS-3. Because (1) the track is the same length for DDS-2 and DDS-3, and (2) there are twice as many bits in the same length of tape, the head passes over twice as much data in the same amount of time.

Fast search is another feature that increases the data transfer rate. Fast search is the process of reading just the sub-code areas to locate particular data on a tape. The sub-code areas include information about user data such as group count, filemark count, setmark count, and block count, which allows the drive to find a particular data group quickly. The tape heads access the sub-code at a speed 100 times that of the normal read/write process. Normal tape speed for DDS-3 is 10.4 mm/s, but in fast search mode, DDS-3 tape speed is 1040 mm/s.

During fast search, the rotational speed of the drum is slightly reduced so that the tape passes over the heads at the same relative speed. Because of the reduced drum speed, the tape head path is at a more acute angle than in normal read mode (Figure 6). Therefore, the head can only read a small amount of data from the track as it crosses it. To make this small piece of data usable, sub-code data is written in small, self-contained units among the user data. With DDS-1 and DDS-2, sub-code data is encoded on the track. However, with DDS-3, sub-code data is in the fragment headers (areas of the tape not intended for recording) and does not use space on the track that could be used to store data.

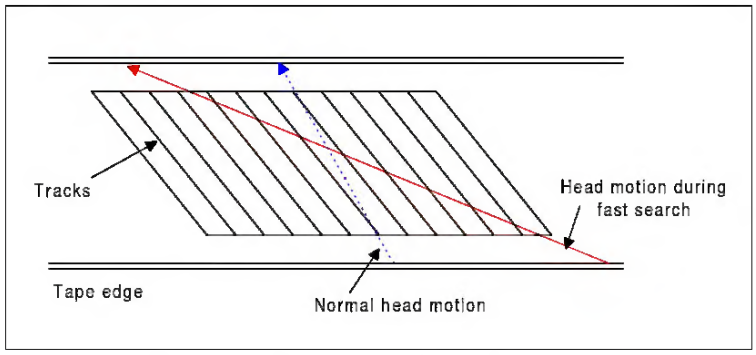

Figure 6: Normal and fast search tape head paths.

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DDS-3's read-after-write (RAW) capability also improves the data transfer rate. RAW refers to the ability of a DDS drive to read and verify data immediately after it has been written. This is possible because of the extra set of read and write heads that DAT drives bave. In the event of an error, the drive can rewrite the incorrect data repeatedly until it is read back successfully. This ability eliminates the need for a time-consuming validation phase.

Improved Reliability

DDS-3 technology offers improved reliability over DDS-1 and DDS-2 technology with better error detection and correction and a more effective automatic bead cleaner.

Error Detection and Correction

DDS formats have three levels of error correction code (ECC): C1, C2, and C3. Additional error detection and correction techniques, such as RAW, data randomizing, checksums, and N-group writing, are also features of DDS-3. These techniques, combined with ECC, provide an extremely higb level of data integrity.

DDS-3 bas improved C1 error detection over DDS-1 and DDS-2. DDS-3 is able to distinguish which block in a block pair is bad and correct only the bad block. This ability decreases the verall error rate since two C1 errors are assumed for every C1 correction with DDS-2. It also decreases tbe need for C2 correction, whicb is used when the maximum number of C1 corrections is reached. Additionally, DDS-3 knows what correction needs to be applied to data before it reached Error Correction Code. This ability allows for spending more time on correction than detection.

Drive Cleaning

One of the best ways to avoid errors is to clean the tape heads regularly[1]. In addition to cleaning the drive regularly with a cleaning tape, DDS-3 has an automatic head cleaner that touches the head every five minutes of tape movement to remove debris during the write or read recovery procedure. Automatic head cleaning also occurs when normal error correction fails.

The DDS-3 internal bead cleaner has an improved design, which provides more effective cleaning over the latest DDS-2 designs. The new sweeper brush (Figures 7 and 8) cleans the head better than previous foam head cleaners. This eliminates occurrences of head-to-tape separation, reducing error rates. The automatic head cleaner enhances reliability and reduces user maintenance requirements, reducing the frequency of cleaning by a conservative factor of four.

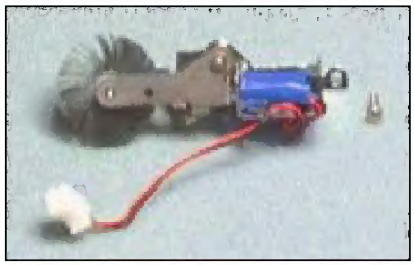

Figure 7: DDS-3 head cleaner.

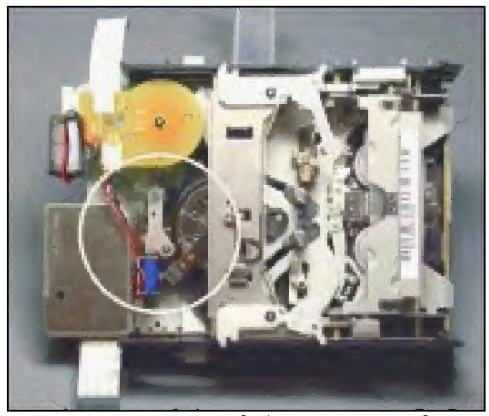

Figure 8: DDS-3 head cleaner in DAT drive.

[1] For information on cleaning DAT drives, please see white paper, *Tape Drives, Media, and the Importance of Cleaning,* document number ECG079.1197.

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DAT Media Durability

The DDS-3 DAT drives use a 12 GB data cassette (Figure 9).

Figure 9: DAT tape cassette (actual size).

Approximately 2000 passes (or 6000 hours of tape pulling) can be made over a section of tape in a DAT drive before performance degradation begins. A *pass* is defined as any forward or reverse motion of the tape media across the read or write heads. *Tape pulling* is defined as anytime the drive is reading, writing, or tensioning the tape. Depending on the backup application and various other factors, up to six passes occur during each backup session. From a practical standpoint, if a tape were used for a weekly backup, it should last for two years. However, because DDS cassettes are so inexpensive, Compaq recommends replacing them sooner to ensure a reliable backup.

Low Total Cost of Ownership

DDS-3 tape drives offer low total cost of ownership in two ways. First, DDS-3 drives are compatible with existing DDS-1 and DDS-2 media. This compatibility provides a natural upgrade path and investment protection for users of existing DDS format devices, reducing total cost of ownership. Because DDS-3 was also developed with future DDS formats in mind, the DDS-3 media are designed to be forward compatible.

Second, DAT cassettes are inherently inexpensive. With other tape storage technologies, the cassette bodies are precision made to align the tape accurately with the heads. With DAT technology, the precision alignment capability is built into the drive mechanism instead. This makes DAT cassettes far less expensive than other forms of tape drive media.

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BACKUP SOFTWARE

Compaq developed the 12/24 GB DAT Drive (Figure 10) in accordance with the DDS-3 specification to provide high-performance, reliable backups for storage requirements of 24 GB or less. Compaq performs extensive hardware and software testing to ensure a highly integrated and compatible solution for Compaq systems.

Note: Please see the appendix for results of performance testing of the Compaq 12/24 GB DAT Drive.

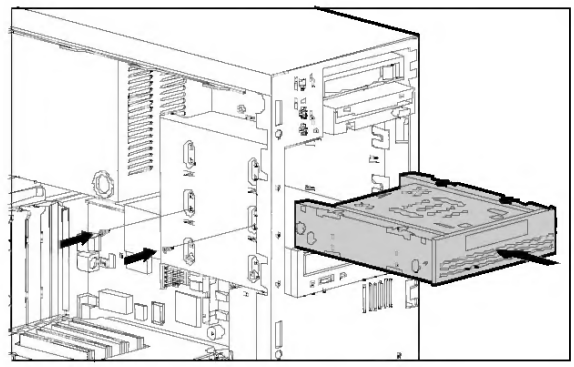

Figure 10: Compaq 12/24 GB DAT Drive being inserted into a ProLiant server.

The 12/24 GB DAT Drive is designed with *TapeAlert* support. TapeAlert is a tape drive status monitoring and messaging utility that automatically detects media and drive problems that could have a negative impact on backup quality. TapeAlert provides easy-to-understand error messages as errors arise and recommends appropriate corrective action.

CA\Cheyenne Software

CA\Cheyenne ARCserve® for Windows NT and for Novell NetWare 3.x and IntranetWare 4.0 all support the Compaq 12/24 GB DAT Drive. ARCserve provides advanced industry features such as:

- RAID-1 real time mirroring
- Disaster-recovery protection
- Integrated virus scanning
- RAID-5 hardware fault tolerance

ARCserve has RAID-1 mirroring and disaster-recovery protection capabilities. In addition, ARCserve's integrated virus scanning feature helps prevent virus infection of the backup media. RAID-5 hardware fault tolerance enables backup and recovery to continue unabated, even in the event of a drive failure.

In addition to ARCserve, CA\Cheyenne has JETserve Plus® backup software, which supports the Compaq 12/24 GB DAT Drive. JETserve Plus is a server-based, ultra high-speed backup product designed for both small, single NetWare server environments and for large NetWare servers. JETserve allows for local backup, restore, and disaster recovery of the entire server in short amount of time.

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Seagate Software

Seagate Backup Exec® for Microsoft Windows NT, Novell NetWare 3.x and IntranetWare 4.0 all support the Compaq 12/24 GB DAT Drive. The Seagate software complements the 12/24 GB DAT Drive with advanced industry features, such as:

- Intelligent disaster recovery
- Dynamic drive pooling in the Windows NT environment
- Fault tolerant backup
- Media mirroring whicb provides RAID (redundant array of independent disks) Level 1 (RAID-1) in the Windows NT environment
- Agent accelerator technology

These software features protect customers' online data in most cases. Intelligent disaster recovery provides the only diskette-based, "point-in-time" recovery option that eliminates the need to re-load the operating system first. Drive pooling and fault tolerant backup features ensure that backups occur consistently by using all available DDS-3 resources. With RAID-1 functionality, customers can mirror backups (one copy for onsite and one for offsite storage). Backup Exec's intuitive user interface provides an easy-to-use approacb to backup and restore, and agent accelerator technology, which maximizes backup speeds, greatly enhances backup performance.

CONCLUSION

DDS-3 is a cost effective, reliable, high-performance backup solution for mid-size companies or branch offices that have storage requirements of 24 GB or less and are running Windows NT or Novell NetWare3.x or IntranetWare 4.0. The new DDS-3 technology has several significant improvements over existing DDS-2 technology, including increased capacity, faster transfer rate, and improved reliability and offers low total cost of ownership. Compaq's 12/24 BG DAT Drive provides a highly integrated backup solution and is supported by tbe Seagate Backup Exec, CA\Cheyenne ARCserve, and CA\Cheyenne JETserve data management software. The 12/24 GB DAT Drive demonstrates Compaq's commitment to providing viable business solutions for all levels of enterprise computing.

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APPENDIX: Performance Test Results

Test 1: Local backup under Microsoft Windows NT 4.0 with Cheyenne ARCserve backup software

Hardware	ProLiant 6000 with three Pentium Pro 200MHz processors, 512 K cache, 320 MB memory, one SMART-2 Array Controller, fourteen 4.3 GB ultra-wide SCSI drives
Operating system	Microsoft Windows NT 4.0
Backup software	Cheyenne ARCserve 6.0 (Build 516)
Backup drive	Compaq 12/24 GB DAT
DAT drive firmware	Version 2.86
Data set per drive	512 MB of 1 MB files
RAIT level	RAIT-0

Results:

Compression Ratio	RAIT Setup	Backup Speed (MB/min)	Restore Speed (MB/min)	Image or File-by-File (FBF)
1:1	1:1	48.31	48.38	FBF
2:1	1:1	91.26	90.99	FBF
4:1	1:1	132.01	132.01	FBF
1:1	1:1	48.71	43.65	Image
2:1	1:1	90.79	45.66	Image
4:1	1:1	130.65	65.05	Image
2:1	2:1	90.72	90.45	FBF
4:1	2:1	254.12	135.53	FBF
2:1	2:1	90.00	45.26	Image
4:1	2:1	239.85	68.52	Image
2:1	2:2	183.62	109.65	FBF
4:1	2:2	224.22	245.92	FBF
2:1	2:2	168.62	92.43	Image
4:1	2:1	237.99	116.29	Image
2:1	4:1	176.20	178.26	FBF
4:1	4:1	260.64	222.59	FBF
2:1	4:2	162.38	86.69	Image
4:1	4:2	232.61	115.43	Image

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Test 2: Local backup under Novell IntranetWare SMP with Cheyenne ARCserve backup software

Hardware	ProLiant 6000 with three Pentium Pro 200MHz processors, 512 K cache, 320 MB memory, one SMART-2 Array Controller, fourteen 4.3 GB ultra-wide SCSI drives
Operating system	Novell IntranetWare SMP
Backup software	Cheyenne ARCserve 6.1
Backup drive	Compaq 12/24 GB DAT
DAT drive firmware	Version 2.86
Data set per drive	512 MB of 1 MB files
RAIT level	RAIT-0

Results:

Compression Ratio	RAIT Setup	Backup Speed (MB/min)	Restore Speed (MB/min)	Image or File-by-File (FBF)
1:1	1:1	51.62	51.86	FBF
2:1	1:1	92.21	91.28	FBF
4:1	1:1	103.14	102.62	FBF
2:1	3:1	142.84	125.23	FBF
2:1	3:2	148.23	135.25	FBF
2:1	5:1	148.23	140.23	FBF

Test 3: Local backup under Microsoft Windows NT with Seagate Backup Exec software

Hardware	ProLiant 6000 with three Pentium Pro 200MHz processors, 512 K cache, 320 MB memory, one SMART-2 Array Controller, fourteen 4.3 GB ultra-wide SCSI drives
Operating system	Microsoft Windows NT 4.0
Backup software	Seagate Backup Exec version 7.0 Rev. 554a
Backup drive	Compaq 12/24 GB DAT
DAT drive firmware	Version 2.86
Data set per drive	512 MB of 1 MB files
RAIT level	RAIT-0

Results:

Compression Ratio	RAIT Setup	Backup Speed (MB/min)	Restore Speed (MB/min)	Image or File-by-File (FBF)
1:1	1:1	50.37	50.79	FBF
2:1	1:1	89.10	91.52	FBF
4:1	1:1	127.17	132.15	FBF
2:1-32k block	1:1	90.70		FBF

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Test 4: Local backup under Novell IntranetWare SMP with Seagate Backup Exec software

Hardware	ProLiant 6000 with three Pentium Pro 200MHz processors, 512 K cache, 320 MB memory, one SMART-2 Array Controller, fourteen 4.3 GB ultra-wide SCSI drives
Operating system	Novell IntranetWare SMP
Backup software	Seagate Backup Exec version 7.0 Rev. 554a
Backup drive	Compaq 12/24 GB DAT
DAT drive firmware	Version 2.86
Data set per drive	512 MB of 1 MB files
RAIT level	RAIT-0

Results:

Compression Ratio	RAIT Setup	Backup Speed (MB/min)	Restore Speed (MB/min)	Image or File-by-File (FBF)
1:1	1:1	50.40	50.40	FBF
2:1	1:1	90.60	91.00	FBF
4:1	1:1	129.30	97.60	FBF

Test 5: Local backup under Novell IntranetWare SMP with Cheyenne JETserve Plus backup software

Hardware	ProLiant 6000 with three Pentium Pro 200MHz processors, 512 K cache, 320 MB memory, one SMART-2 Array Controller, fourteen 4.3 GB ultra-wide SCSI drives
Operating system	Novell IntranetWare SMP
Backup software	Cheyenne JETserve Plus version 4.0
Backup drive	Compaq 12/24 GB DAT
DAT drive firmware	Version 2.86
Data set per drive	512 MB of 1 MB files
RAIT level	RAIT-0

Results:

Compression Ratio	RAIT Setup	Backup Speed (MB/min)	Restore Speed (MB/min)	Image or File-by-File (FBF)
2:1	1:1	91.29	91.09	Image
2:1	2:1	178.60	-	Image
2:1	3:1	270.66	-	Image
2:1	4:1	352.09	-	Image
2:1	2:2	182.31	-	Image
2:1	4:2	180.19	-	Image
2:1	8:2	361.41	-	Image

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